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"Interperitoneal and visceral temperature values — "

INTRAPERITONEAL AND VISCERAL TEMPERATURE VALUES AS

INFLUENCED BY EXTERNAL ENVIRONMENT

by

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S.B.R

INTRAPERITONEAL AND VISCERAL TEMPERATURE VALUES

AS INFLUENCED BY EXTERNAL ENVIRONMENT

The custom of applying heat or cold to the abdominal wall for the relief of pain within the abdominal cavity is very ancient. That this method is often effective is a fact of common knowledge. The careful observation of intraperitoneal changes of temperature when heat or cold is applied externally seems a logical step to ascertain the mode of action of these physiotherapeutic agents. In arriving at the data which are here presented guinea pigs and rabbits were used in the laboratory, surgical patients in the operating room, and a few medical patients in the wards.

Our thermoelectric determinations were made by means of a portable thermoelectric apparatus constructed to suit our individual requirements by Dr. B. McGlone, of the Department of Physiology, Medical School, University of Pennsylvania. Dr. McGlone has done much original work with thermocouples, and both by theory and by application has found insulated constantan and manganin wires of No. 26 gauge to work the most satisfactorily. We had four special electrodes built, and were then equipped to determine the temperature of any tissue of the body. The terminals were detachable, and before use in the intraperitoneal cavity of a patient they were autoclaved at fifteen pounds pressure for twenty minutes. We had no deleterious effects from these determinations in any of the fifteen patients examined on the operating table, or the two medical cases (ascites) examined in the ward. In the special terminal constructed for these latter two cases a No. 14 French Catheter was used.

Standardizations of the thermocouples were made daily. It was found that in all the termanals except the skin terminal there were at times marked shifts of the apparent zero (i.e., parasitic currents). In the skin terminal the changes were not so great. Marked variations in normal temperatures, at least in the external temperatures, came from the struggles of the animal which had just had a subcutaneous injection of sodium amytal followed bu the insertion of a rectal thermometer. The animals which did not resent this routine procedure had no marked rise in temperature. Hence the more nearly accurate temperatures for undisturbed guinea pigs would be those of the lower values.

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The determinations were made upon the animals while they were under the influence of small doses of sodium amytal, injected hypodermically, and repeated as needed. Just enough was given to prevent the animals from moving and suffering pain, except in the use of the diathermy in which case it became necessary to give very large doses to prevent excessive hyperventilation, as the hyperventilation tended to lower the temperature. Thus the experimental responses of the animals especially in the application of heat and cold approached those of the true responses of patients. In taking all determinations upon the animals each animal lay upon its left side, the abdominal insision was made in the center of the

midline, and cold or heat was applied to the right (or upper) side.

Always upon opening the peritoneal cavity the temperature noted there would be less than the temperature found using the same terminal between the legs or upon the upper body surface. The cause was presumably the entrance of air at a lower (room) temperature. The temperatures recorded in the tables were maximum temperatures, i.e., the terminal would be held in the same place for from three to five minutes- in all cases until there had been a full minute of contact with no further rise in temperature. Hence these tables represent selected values from great numbers of individual observations. The great variations and low values of the rectal temperatures were possibly caused by faecal contamination. Because of this same great variability the rectal temperatures were not considered to be of great significance. They were included in the tables because of the interest in their variations, and to show that the ordinary use of a rectal thermometer, contrary to the opinion of some, may be as full of errors as the use of the oral thermometer.

EXPERIMENT ONE- TEST OF NORMALS

The normal intraperitoneal temperature of the different regions was found to vary somewhat in the different individual animals. In practically all instances, both with guinea pigs and with rabbits, it was noted that a very warm location was just beneath the upper parietal wall. The temperature in the center mass of intestines was usually the same or very slightly lower. The temperature in the pelvis was usually slightly lower than that of the right (upper) side; and the temperature with the terminal against the diaphragm was usually equal to or slightly above that beneath the upper parietes. The comparative temperature values above the lower parietes varied considerably, probably influenced by the temperature of the table upon which the animal lay. The temperature just inside the peritoneal cavity was lowest of all. If the opening was small and the viscera undisturbed for a period of time this value tended to more nearly approach the average intraperitoneal temperature value. For normal values see Tables I to IV.

Table I.
Guinea pigs.
Normal External Surface Temperatures.

	Rectum	Between the hind legs	Between the front legs	Center of midline of abdomen	Center of upper side
Animal No. 1.	39.6	39.0	38.7	38.5	38.8
" " 2.	38.1	37.6	37.7	36.9	37.5
" " 3.	37.8	38.1	38.2	36.7	37.9
" " 4.	38.1	38.3	38.5	38.2	38.4
" " 5.	38.0	38.2	38.8	38.2	38.8
" " 6.	34.9	36.1	37.2	36.2	37.1
" " 7.	39.0	37.1	38.3	37.5	38.5
" " 8.	35.3	38.0	38.1	37.8	38.0
" " 9.	36.2	39.2	39.1	38.7	39.0
" " 10.	35.6	38.5	38.7	39.4	38.5
" " 11.	36.3	36.2	36.8	36.4	36.5
" " 12.	36.7	36.7	37.4	37.2	36.7
Average	37.1	37.7	38.1	37.6	38.0

Table II.
Guinea pigs.
Normal Intraperitoneal Temperatures.

	Rectum	Beneath upper parietes	Center mass of intestines	Pelvis	Beneath the diaphragm	Just inside incision	Above lower parietes
Animal No. 1.	39.6	38.9	38.8	38.9	38.2	38.4	38.1
" " 2.	38.1	37,5	37.8	37.3	37.6	37.1	37.4
" " 3.	37.8	38.1	38.1	37.9	38.2	37.8	38.1
" " 4.	38.1	39.6	39.5	39.4	39.1	38.7	39.7
" " 5.	37.9	38.4	38.3	38.2	38.4	37.5	38.1
" " 6.	34.9	37.0	36.9	36.8	37.1	36.8	37.1
" " 7.	39.0	39.0	39.9	38.9	40.1	38.2	39.3
" " 8.	35.3	37.4	37.9	37.1	38.0	36.8	37.0
" " 9.	34.6	37.0	37.2	36.5	37.4	36.8	36.4
" " 10.	33.9	39.6	38.7	38.4	38.8	38.2	38.9
" " 11.	35.0	37.9	37.8	37.6	37.8	37.5	37.2
" " 12.	37.5	38.6	38.7	38.4	38.8	38.2	38.9
Average	36.8	38.0	38.1	37.7	38.1	37.5	37.7

Table III.
Rabbits.
Normal External Surface Temperatures.

	Rectum	Between the hind legs	Between the front legs	Center of midline of abdomen	Center of upper side
Animal No. 1.	38.1	38.6	38.0	37.4	37.9
" " 2.	37.9	39.7	40.2	39.9	39.8
" " 3.	38.5	39.7	39.5	39.4	39.6
" " 4.	37.6	39.7	39.4	39.5	40.0
" " 5.	37.8	37.8	40.4	40.0	40.3
" " 6.	37.6	39.2	38.9	38.7	39.0
Average	38.1	39.6	39.3	39.1	39.5

Table IV.
Rabbits.
Normal Intraperitoneal Temperatures.

	Rectum	Beneath upper parietes	Center mass of intestines	Pelvis	Beneath the diaphragm	Just inside peritoneal cavity	Above lower parietes
Animal No. 1.	38.5	39.1	40.3	39.3	39.4	39.1	39.4
" " 2.	37.8	38.5	39.0	38.8	38.9	38.1	39.1
" " 3.	38.5	40.0	38.8	38.7	39.8	39.1	39.6
" " 4.	39.1	40.0	39.9	39.9	40.0	39.2	39.7
" " 5.	37.5	37.9	37.4	38.8	39.4	38.9	37.4
" " 6.	39.2	39.1	39.2	39.2	39.1	37.3	39.1
Average	38.4	39.1	39.1	39.1	39.4	38.6	30.0

EXPERIMENT TWO--EFFECT OF COLD

In studying the effect of cold the animal lay on its left side and the use of icebags was employed. These were supported upon each side, and allowed to rest upon the upper (right) side of the animal. In the case of the guinea pigs covers were used upon the bags in the same manner that they are upon patients. The rabbits had long fur and the covers of the icebags were removed during the experiments.

Table V.
Guinea pigs.
The Effect of Cold Applied to the Abdominal Wall Upon the Temperature in Various Parts of the Intraperitoneal Cavity.

		Rectum	Beneath upper parietes	Beneath the diaphragm	Center of mass of intestines	Above lower parietes	Pelvis	Just inside incision
Animal No. 1.	Before	37.7	37.1	37.2	37.4	36.2	36.9	36.7
34 min.	After	33.0	23.6	30.8	31.3	32.4	30.3	31.8
	Decrease	4.7	13.5	6.5	6.1	3.7	6.6	4.9
Animal No. 2.*		37.9	38.4	38.4	38.3	37.7	38.2	37.5
	18 min.	33.9	29.4	34.2	34.3	35.6	33.9	34.3
		4.0	9.0	4.2	4.0	22.1	4.4	3.1
Animal No. 3.		34.9	37.0	37.1	36.9	36.1	36.8	36.8
	45 min.	30.2	24.5	30.9	30.7	32.6	30.5	32.5
		4.7	12.5	6.2	6.2	3.5	6.3	4.1
Animal No. 4.		34.0	35.5	35.2	35.4	34.5	35.3	35.1
	75 min.	33.5	31.7	33.5	33.6	33.8	33.4	33.8
		0.5	3.8	1.7	1.8	0.7	1.9	1.3
Animal No. 5.		39.6	38.9	38.2	38.8	38.1	38.9	38.4
	48 min.	34.4	27.0	33.0	33.7	35.0	33.5	34.5
		5.2	11.9	5.2	5.1	3.1	5.4	3.9
Animal No. 6.		38.1	37.5	37.6	37.8	37.4	37.3	37.1
	43 min.	33.8	27.7	34.9	33.1	34.6	36.4	34.0
		4.3	9.8	3.7	4.7	2.8	4.9	3.1
Animal No. 7.*		37.8	38.1	38.2	28.1	38.1	37.9	37.8
	25 min.	34.1	30.3	34.6	34.5	36.0	33.9	35.1
		3.7	7.8	3.6	3.6	2.1	4.0	2.7
Animal No. 8.		38.1	39.6	39.1	39.5	39.8	39.4	38.7
	54 min.	31.6	25.4	32.3	32.8	35.8	32.5	33.8
		6.5	14.2	6.8	6.7	4.0	6.9	4.9
Animal No. 9.		34.9	37.0	37.1	36.9	37.1	36.8	36.8
	49 min.	29.9	24.2	31.4	31.2	34.0	31.0	32.8
		5.0	12.8	5.7	5.7	3.1	5.8	4.0
Animal No.10.		39.0	39.0	40.1	39.9	39.2	38.9	38.3
	67 min.	34.1	25.7	34.1	33.9	36.9	32.8	33.8
		4.9	13.3	6.0	6.0	3.3	6.1	4.5

Table V, con.

Animal No. 11.	35.3	37.4	38.0	38.0	37.0	37.1	36.8
36 min.	31.1	27.6	33.5	33.5	34.1	32.6	33.3
	4.2	9.8	4.5	4.5	2.9	4.5	3.5
Animal No. 12.	34.6	37.0	37.4	37.2	36.4	36.5	36.8
46 min.	29.6	25.7	31.6	31.5	33.5	30.6	33.1
	5.0	11.3	5.8	5.7	2.9	5.9	3.7
Average decrease	4.7	11.3	5.1	5.2	3.0	5.4	3.8

* Not averaged in.

Table VI.
Rabbits.
The Effect of Cold Applied to the Abdominal Wall Upon the Temperature in Various Parts of the Intraperitoneal Cavity.

	Rectum	Beneath upper parietes	Beneath the diaphragm	Center of mass of intestines	Above lower parietes	Pelvis	Just inside peritoneal cavity
Animal No. 1. Before	36.5	37.9	38.3	37.8	37.8	37.8	38.1
48 min. after	33.0	30.4	34.4	34.0	35.8	33.9	34.2
Decrease	3.5	7.5	3.9	3.8	2.0	3.9	3.9
Animal No. 2.*	38.8	38.9	39.1	38.9	38.7	39.1	38.4
13 min.	37.6	35.8	37.7	37.3	37.7	37.4	37.2
	1.2	3.1	1.4	1.6	1.0	1.7	1.2
Animal No. 3.	38.5	39.1	39.4	40.3	39.4	39.3	39.1
46 min.	34.3	32.2	35.5	36.4	35.9	35.4	35.4
	4.2	6.9	3.9	3.9	3.5	3.9	3.7
Animal No. 4.	37.8	38.5	38.9	39.0	39.1	38.8	39.1
45 min.	33.1	30.4	34.8	35.0	36.7	34.7	35.7
	4.7	8.1	4.1	4.0	2.4	4.1	3.4
Animal No. 5.	38.5	40.0	39.8	38.8	39.6	38.7	39.1
34 min.	35.1	33.6	36.8	35.9	38.0	35.7	37.2
	3.4	6.4	3.0	2.9	1.6	3.0	1.9
Animal No. 6.	39.1	40.0	40.0	39.9	39.7	39.9	39.2
51 min.	35.5	32.3	36.4	36.5	36.9	36.3	36.5
	3.6	7.7	3.6	3.4	2.8	3.6	2.7
Average	3.9	7.3	3.7	3.6	2.5	3.7	3.2

*Not averaged in.

When the ice bar was applied for thirty minutes or longer the above results were obtained. The decrease in intraperitoneal temperature was greatest just beneath the upper parietes; it was least just above the lower parietes; and was intermediate in the mass of intestines in the center. Likewise the falls of temperature in the pelvis and against the diaphragm were less than that against the upper parietes.

Table VII.
Time as a Factor in the Decrease in the Intraperitoneal Temperature.

Minutes, total decrease during

	1	2	3	5	10	15	20	25	30	45	60	75
Guinea pig No. 1.	0.2	0.6	1.0	1.4	5.2	7.8	9.0	105	130	134		
							19					
" " 2	0.4	1.8	3.0	3.6	7.0	8.0	9.0					
			4			13	16	26				
" " 3.	0.0	0.0	0.2	0.2	0.3	0.5	0.9	2.8	3.3	117	126	
			3									
" " 4.	1.2	1.8	2.6	3.4								
					11				31			
same animal at a different time	0.1	0.1	0.2	0.5	0.5	1.2	1.9	2.1	2.3	2.9	3.5	3.9
						13	21	26	32	44	48	
Rabbit No. 1.	0.2	0.3	0.7	1.3	2.8	3.4	4.3	5.1	6.0	7.0	7.5	
				4		13						
" " 2.	0.2	0.5	0.8	1.1	2.0	2.2						

Table VII illustrates that the greatest decrease per unit of time of the intraperitoneal temperature occurs during the period between ten and forty-five minutes after the application of the cold.

Table VIII.
Guinea pigs.
Effects of Shivering and Convulsions Upon Intraperitoneal Temperature.

Minutes, total change after cold applied

	0	2	5	10	15	20*	25	30	34**
Guinea pig No. 1.	37.1	36.5	35.6	31.9	29.4	28.1	26.6	24.0	23.6

35	36	38	39	40	44
24.3	24.9	25.3	25.5	25.6	26.2

*Shivering began.
**Convulsions began; shivering continued.

Table VIII con.

Temperature decreased 13.5 degrees in 34 min.
Temperature then increased 2.6 degrees in 10 min.

Guinea pig No. 2.	0	2	5*	0**	5	11	15	21
	39.4	37.6	36.0	35.5	35.5	35.1	34.4	33.6
	25	31	35.1	40	45	60	75	
	33.4	33.2	33.1	33.0	32.6	32.0	31.7	

*Shivering severely-ice removed- temperature had dropped 3.4 degrees in 5 min.
**Ice reapplied. Shivered severely, decrease now of 3.9 degrees in 75 min.

Shivering and (in one case) convulsions acted to prevent a rapid decrease, or to actually increase, the temperature. In one animal (guinea pig) in five minutes cold decreased the intraperitoneal temperature 3.4 C. (39.4 C. to 36.0 C.). Shivering then became constant and pronounced, and during a later period of seventy-five minutes the temperature decreased 3.8 C. further (from 35.5 C. to 31.7 C.). In another animal in 34 minutes cold reduced the temperature 13.4 C. (37.0 C. to 23.6 C.); convulsions set in and in seven minutes the temperature had risen 2.6 C. (to 26.2 C.). See Table VIII.

Table IX.
Intraperitoneal Temperature Changes After Removal of External Cold.

	Temp. before cold applied	Cold applied (min.)	Degrees of decrease	Lowest temp. value	Interval at room temp. (min.)	Degrees of increase in temp.	Resulting temperature
Guinea pig No. 1.	38.4	18	9.0	29.4	92	5.9	35.3
" " 2.	35.5	105	3.8	31.7*	47	3.6	35.3
Rabbit No. 1.	37.9	48	7.5	30.4	48	3.7	34.1

*Guinea pig was shivering most of time.

After removal of the ice bag the intraperitoneal temperature rose and gradually approached the normal. If the animal shivered the rise was much more rapid, and the normal temperature was more nearly approached. In one animal in eighteen minutes there was a temperature decrease of 9.0 C. (38.4 C. to 29.4 C.); in ninety-two minutes after removal of the cold the temperature rose 5.9 C. (29.4 C. to 35.3 C.). See Table IX.

EXPERIMENT THREE--EFFECT OF HEAT

A. Application of Local Heat.

In studying the effects of local heat the animal lay in the same position (i.e.,)on its left side), and hot water bags were employed. These applied temperatures did not exceed 50 degrees Centigrade.

Table X.
Guinea pigs.
The Effect of Heat Applied to the Abdominal Wall upon the Temperature Values in the Intraperitoneal Cavity.

	Rectum	Beneath upper parietes	Beneath diaphragm	Center of mass of intestines	Above lower parietes	Pelvis	Just inside peritoneal cavity
No. 1.* After	38.2	43.3	39.5	39.9	39.0	39.3	38.6
26 min. before	38.1	39.6	39.1	39.5	38.9	39.4	38.7
Increase	0.1	3.7	0.4	0.4	0.1	-0.1	-0.1
No. 2.	40.9	44.1	40.7	42.1	38.5	38.8	38.3
560min.	39.0	39.0	40.1	39.9	39.2	39.7	38.3
	1.9	5.1	0.6	2.2	-0.7	-0.9	0.0
No. 3.	34.1	38.3	37.2	38.2	36.7	35.9	36.4
40 min.	33.9	34.6	36.5	36.6	35.2	35.8	36.3
	0.2	3.7	0.7	1.6	1.5	0.1	0.1
No. 4.	35.9	42.1	38.7	39.6	38.6	37.5	37.6
46 min.	35.0	37.9	37.8	37.8	37.2	37.6	37.5
	0.9	4.2	0.9	1.8	1.4	-0.1	0.1
No. 5.	37.6	42.0	39.1	39.6	39.4	38.3	38.1
37 min.	37.5	38.6	38.8	38.7	38.9	38.4	38.2
	0.1	3.4	0.3	0.9	0.5	-0.1	-0.1
No. 6.	39.9	44.4	40.1	41.6	41.7	39.1	39.1
52 min.	38.0	39.3	39.4	39.3	39.1	39.2	39.1
	1.9	5.1	0.7	2.3	2.6	-0.1	0.0
No. 7.	39.2	45.1	40.0	41.8	41.8	38.9	38.8
56 min.	37.6	39.0	39.2	39.1	38.8	38.8	38.7
	1.6	6.1	0.8	2.7	3.0	0.1	0.1
No. 8.	38.0	42.9	37.8	38.8	38.6	36.7	36.7
42 min.	35.9	36.7	36.8	36.7	36.5	36.5	36.5
	2.1	6.2	1.0	2.1	2.1	0.2	0.2

Table X con.

No. 9.	38.5	43.7	38.4	39.6	39.7	37.6	37.5
50 min.	36.1	37.4	37.4	37.4	37.3	37.3	37.3
	2.4	6.3	1.0	2.2	2.4	0.3	0.2
No. 10.	38.1	43.5	38.9	39.7	39.5	38.4	38.2
39 min.	37.2	38.5	38.6	38.6	38.3	38.3	38.1
	0.9	5.0	0.3	1.1	1.2	0.1	0.1
No. 11.	37.7	41.8	37.9	38.5	38.4	37.2	37.1
40 min.	36.8	37.3	37.5	37.5	37.1.	37.3	37.2
	0.9	4.5	0.4	1.0	1.3	-0.1	-0.1
No. 12.	37.8	41.9	39.3	39.6	39.7	36.6	36.9
35 min.	37.6	38.8	39.0	38.9	38.6	36.7	36.7
	0.2	3.1	0.3	0.7	1.1	-0.1	0.2
Average	1.2	4.8	0.6	1.7	1.5	-0.05	0.1

*Not included in average.

Table XI.
Rabbits.
The Effect of Heat Applied to the Abdominal Wall upon the Temperature Values in the Intraperitoneal Cavity.

	Rectum	Beneath upper parietes	Beneath diaphragm	Center of mass of intestines	Above lower parietes	Pelvis	Just inside peritoneal cavity
No. 1.* After	36.2	43.2	37.0	38.3	36.2	36.4	35.9
27 min. before	35.9	35.8**	36.0	35.8	35.8	35.8	34.5
Increase	0.3	7.4	1.0	2.5	0.4	0.6	1.4
No. 2.	36.0	41.0	35.2	37.1	36.9	37.2	37.1
65 min.	33.1	33.7**	34.1	34.1	33.5	34.0	33.6
	2.9	7.3	1.1	3.0	3.4	3.2	3.5
No. 3.	39.8	45.0	40.1	41.2	39.9	40.1	38.7
35 min.	39.2	39.1	39.1	39.1	39.1	39.2	37.3
	0.6	5.9	1.0	2.1	0.8	0.9	1.4
No. 4.	39.8	44.6	39.8	40.7	40.6	40.8	40.3
48 min.	37.7	38.4	38.6	38.4	38.4	38.5	38.0
	2.1	6.2	1.2	2.3	2.2	2.3	2.3

Table XI. con.

No. 5.	40.1	43.7	39.4	40.5	40.6	40.9	40.5
45 min.	37.0	37.9	38.1	37.9	37.9	38.0	37.7
	3.1	5.8	1.3	2.6	2.7	2.9	2.8
No. 6.	40.2	44.8	41.1	40.9	41.1	41.3	40.3
48 min.	38.1	39.[illegible]	39.5	39.2	39.2	39.3	38.1
	2.1	5.5	1.6	1.7	1.9	2.0	2.2
Average increase	2.1	6.0	1.0	2.3	2.2	2.3	2.5

*Not included in average.
***Previously reduced by cold.

When heat was applied locally to the external abdominal wall by far the greatest rise in temperature occurred in the area just beneath the area of application of the heat. A very definite increase was also observed in the center of the mass of intestines and in the pelvis. These increases were proportionately greater in the rabbits than in the guinea pigs. (Table X and Table XI.)

Table XII.
Time as a Factor in the Increase in Intraperitoneal* Temperatures as a Result of Hot Water Bottles Applied to the Abdominal Wall.

total increase in minutes

	1	2	3	9	11	15	20	25				
Guinea pig No. 1.	0	0.2	0.2	0.2	1.0	1.4	3.3	3.6				
	1	2	4	6	10	16	20	25	30			
" " 2.	0	0.1	0.4	0.7	0.8	1.2	2.1	3.9	5.0			
	1	2	3	5	11	15	20	27				
Rabbit No. 1.	1.5	2.3	2.9	3.9	5.7	6.4	7.0	7.4				
	1	2	3	7	12	15	20	25	30	45	60	65
" " 2.	0.8	1.4	1.8	2.8	3.2	3.7	4.2	4.2	4.2	6.5	7.1	7.2

*Beneath upper parietes.

When a hot water bottle was applied to the external parietes as hot as possible without causing distress (distress occurred at a temperature between fifty degrees Centigrade and fifty-two degrees Centigrade) it was usually found that the subjacent intra-

peritoneal temperature did not undergo change as quickly as when cold was applied. Fifteen or even twenty minutes were usually required to produce an appreciable change. The continued application of heat after thirty to forty-five minutes caused a more gradual increase in the subjacent temperature than had occurred during the previous period. See Table XII.

Table XIII.
Intraperitoneal Temperature Changes After Removal of External Heat.

	Temp. before heat applied	Heat applied (min)	Degrees incr. in temp.	Highest elevation of temp.	Interval at room temp.	Degrees decr. in temp	Resulting temp.	Total time interval	Total decrease	Resulting temp.
G.pig No.1.	39.6	25	3.7	43.3	20	4.2	39.1	120	6.7	36.6
" " 2.	39.0	30	5.1	44.1	88	3.8	40.3	14	5.7	38.4
Rabbit " 1.	35.8	27	7.4	43.2	27	6.9	36.3	122	10.4	32.8
" " 2.	33.7	65	7.3	41.0	19	3.5	37.5	115	8.7	32.3

When the external heat was removed the intraperitoneal temperature fell rapidly, especially at first. After the temperature approached normal, which ordinarily occurred in less time than the elevation had required, the rate of temperature decrease became less; and without fail the temperature became even lower than it originally had been. For instance, one animal (guinea pig) had an original temperature of 39.0; heat was applied for thirty minutes with an increase of 5.1 C. (to 44.1 C.); in eight minutes at room temperature (28.0 C.) the temperature decreased 3.8 C. (to 40.3 C.); in six additional minutes it made a further decline of but 1.9 C. (to 38.4 C.). (Table XIII.)

Table XIV.
Comparison of the Effect of Heat in the Elevating of Intraperitoneal Temperatures from Subnormal towards Normal and from Normal to above Normal.

	Normal temp.	Ice bag applied	Degrees decrease	Temp. resulted	Heat applied	Degrees increase	Temp. resulting	Heat further applied (not	Degrees further increase	Temp. resulting
Rabbit No.1.	38.9	13	3.1	35.8	4	3.3	39.1	11	3.1	42.2
" " 2.	37.9	48	7.5	30.4	54*	3.3	33.7	24	4.0	37.7
								45	3.1	40.8

*At room temperature-25 C.

When the temperature of an animal was below normal, as occurred following the application of an ice bag, the applied heat required less time to elevate the temperature up to the normal than was then required to elevate the temperature a like amount above normal. Applied heat required less time to raise a depressed temperature than had previously been required by applied cold to lower the temperature any stated amount. One animal (rabbit) had a normal temperature of 38.9 C.; an ice bag was applied for thirteen minutes giving 3.1 C. decrease (to 35.8 C.). Then a hot water bottle was applied for four minutes, giving 3.3 C. increase in temperature (to 39.1 C.); during the eleven succeeding minutes, having been reheated as needed, it raised the temperature but 3.1 C. (to 42.2 C.) (Table XIV.) In one instance in which an animal (rabbit) shivered considerably while under the applications of cold, and also after its removal while recovery was taking place at room temperature (28.0 C.), the shivering ceased almost immediately upon the application of a hot water bottle; and that result was noted before any appreciable rise of temperature had occurred intraperitoneally.

Table XV.
The Difference in External and Simultaneous Intraperitoneal (beneath upper parietes) Temperatures
During the Application of Cold.

Guinea pig No. 1.	Internally	35.1	33.5	33.3	32.6	31.8			
	Externally	19.4	24.2	23.6	17.0	18.5			
	Difference	15.7	9.3	9.7	15.6	13.3			
Rabbit No. 1.	Internally	37.9	36.2	35.3	34.9	34.2	32.6	31.7	30.4
	Externally	20.8	21.7	23.6	25.1	24.1	21.4	16.5	17.3
	Difference	17.1	14.5	11.7	[illegible]	10.1	11.2	15.2	13.1

Table XVI.
The Difference between External and Simultaneous Subjacent Intraperitoneal Temperatures During the Application of Heat.

	total time in minutes						
		2	5				
Guinea pig No. 1.	Ext.	49.2	50.8				
	Int.	39.8	43.3				
	Dif.	9.4	7.5				
		4	6	15	30	45	60
" " 2.		40.5	43.0	42.6	49.5	47.5	47.7
		39.4	39.7	40.0	40.0	41.5	42.7
		1.1	3.3	2.6	9.5	6.0	5.0

Table XVI. (con.)

total time in minutes

	2	10	19	
Rabbit No. 1.	52.0	51.5	52.0	47.5
	37.3	40.2	40.8	41.0
	14.7	11.3	11.2	56.5

The difference between the temperature of the external skin beneath the ice bag and the temperature of the subjacent intraperitoneal location is greater than the difference when a hot water bottle is in use. Theoretically this is true because of the following facts: the average external temperature in that location was 38.0 C. for guinea pigs and 39.5 C. for rabbits. In man the accepted oral temperature is 37.0 C. The external temperature can not go above fifty degress Centigrade (or fifty-two degress Centigrade) without causing distrees from burning. Hence in man this is a theoretical maximum difference of fifteen degrees Centigrade (fifty-two degrees minus thirty-seven degress). Likewise the external temperature in man can be depressed, theoretically, to approach the zero point, a maximum difference of thirty-seven degrees (thirty-seven degrees minus zero degrees). Actually in the animals the difference was not as great, having in these cases been found to vary from 9.3 C. to 17.1 C. with the ice bag. In the case of heat the difference in these temperatures was found to vary from 1.1 C. to 14.7 C. See Table XV and Table XVI.

B. Application of Diathermy.

Diathermy was administered by means of a standard clinical machine manufactured by the High Tension Co., (Type F30Z). The electrodes were commercial zinc-lead applied over compresses moistened in saturated saline solution. These were kept in position by elastic strips. The diathermy machine establishes a magnetic field which prohibits accurate thermo-couple readings, both while the machine is in operation and shortly after the current is turned off. Thermometers must therefore be used to take internal temperatures in conjunctio with diathermy. Although Sampson[1] says, "Twenty-five or thirty minutes (is) the average time for a diathermy treatment", these tests were all run from forty-five minutes to several hours since the average abdominal operation requires more than thirty minutes time. The electrodes were at times applied on opposite sides of the body at the level of the liver and diaphragm;

1. C. M. Sampson; Practice of Physiotherapy; C. V. Mosby Co., St. Louis, Mo.; 1926; p. 123.

in some instances, especially with the thermometer in the rectum, they were of the cuff variety and were applied to the hind legs. When the animals were under the influence of but small doses of sodium amytal they objected immediately and vigorously if the current was turned on strong enough to cause a burn. Abnormally rapid and deep respirations prevented marked elevations in temperature unless large doses of sodium amytal were used. The highest readings herein presented were obtained by this means.

Table XVII.
Changes in the Intraperitoneal Temperature Produced
by Diathermy with the Electrodes
Applied about the Liver.

minutes

		0	3	5	8	13	18	25	30	35	40	45
G.pig No.1.	Rectum.	35.0	35.0	35.2	35.7	35.6	35.6	35.0	34.3	34.8	34.8	34.8
	Subdiaphragm.	37.8	38.7	[illegible]	40.[illegible]	41.[illegible]	41.7	42.1	42.5	43.0	43.5	[illegible]
	Pelvis	37.6	37.7	37.8	37.5	38.0	38.3	38.4	38.5	39.0	[illegible]	39.4

		0	2	5	10	15	20	25	30	35	40	45	52	57	62
Rabbit No.1	Rectum.	40.3	40.3	40.4	40.4	40.[illegible]	40.5	40.6	40.6	40.7	40.8	40.9	41.0	41.1	41.2
	Subdiaphragm.	40.3	40.5	40.6	40.6	40.7	40.8	40.9	41.0	41.[illegible]	41.[illegible]	41.6	41.9	42.1	42.3
	Pelvis.	40.5	40.5	40.5	40.4	40.6	40.7	40.8	40.8	41.0	40.1	41.4	41.6	41.8	41.9

		0	3	6	11	16	20	23	28	33	40	48
Rabbit No.2.	Rectum.	38.3	38.3	38.3	38.4	38.2	38.3	38.3	38.3	38.4	38.4	38.4
		40.5	40.5	40.5	40.5	40.6	40.6	40.6	40.7	40.7	40.8	40.8
		40.3	40.4	40.3	40.4	x	40.6	40.7	40.7	40.7	40.8	40.8

With the electrodes applied in the region of the liver and diaphragm by far the greatest increase in temperature was in the subdiaphragmatic area. (Table XVII.) Table XVII also shows the rectal temperature of one animal (guinea pig) which had from the first a marked rise in subdiaphragmatic temperature; but in which after ten minutes the rectal temperature began to decline and this decline persisted to below the normal. The normal temperature was 35.0 C. In ten minutes the rectal temperature was 35.7 C. It then began to fall and in fifteen more minutes was 35.0 C. In five minutes more it sank to 34.3 C., and then rose to 34.8 C. where it persisted for ten minutes despite a steady rise in subdiaphragmatic temperature.

Table XVIII.
Changes Produced in the Intraperitoneal Temperatures by Diathermy, with the Electrodes applied about the Hind Legs.

time in minutes

	0	2	6	10	15	20	23	28	33	38	43	45
G.pig No.1 Rectum	34.3	34.4	34.7	34.9	35.5	36.2	37.2	38.3	40.5	41.6	43.9	45.0
Subdiaphragm.	37.3	37.6	37.7	37.5	38.1	38.4	38.7	38.9	39.1	39.3	39.3	39.3
Pelvis	37.8	37.8	38.0	38.7	39.1	39.8	40.6	41.3	42.4	43.3	44.0	44.5

	0	2	4	9	15	21	25	30	36	40	45	61	76	90	96
Rabbit No. 1.	37.7	37.7	37.7	37.8	37.8	37.9	37.9	37.8	38.2	38.5	38.5	38.9	39.1	39.3	39.4
	38.6	38.8	38.8	38.9	39.0	39.1	39.1	39.2	39.3	39.4	39.5	39.8	40.5	40.2	40.2
	38.9	38.8	38.8	38.9	39.0	39.1	39.1	39.1	39.2	39.3	39.4	39.8	40.0	40.1	40.1

With the electrodes applied to the hind legs the temperature in the pelvis soon became slightly greater than that in the rectum, with the temperature in the subdiaphragmatic area markedly less. This was not always the case, as sometimes the rectal temperature was lower than the other two. But because of the decidedly lower normal rectal temperature the increase in degrees averaged more in the rectum. The temperature in the subdiaphragmatic area rose comparatively slowly. (Table XVIII.)

Table XIX.
Time as a Factor in the Increase in Intraperitoneal Temperatures from Diathermy.

total temperature increase shown by minutes

	temp.	3	5	8	13	20	25	30	35	40	45
G.pig No.1* Rectum	35.0	0.0	0.3	0.7	0.6	0.6	0.0	-0.7	-0.2	-0.2	-0.2
Subdiaphragm	37.8	0.9	1.3	2.8	3.4	3.9	4.3	4.7	5.2	5.7	7.0
Pelvis	37.6	0.1	0.1	0.1	o.4	0.7	0.8	0.9	1.4	1.4	1.8

		2	5	8	13	20	25	30	35	40	45	68
G.pig No.2** Rectum	34.5	0.1	0.4	0.6	1.0	1.5	2.7	4.0	6.2	7.5	9.5	10.7
Subdiaphragm	37.6	0.0	-0.1	0.0	0.3	0.5	0.9	1.1	1.4	1.5	1.5	1.[illegible]
Pelvis	37.8	0.0	0.2	0.9	1.3	2.0	2.8	3.5	4.6	5.5	6.2	6.7

Table XIX, con.

		2	5	10	15	20	25	30	35	40	45	52	57	62
Rabbit No.1*. Rectum	40.3	0.0	0.1	0.2	0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.8	0.9
Subdiaphragm.	40.6	0.0	0.0	x	0.1	0.1	0.3	0.4	0.6	0.7	1.0	1.3	1.5	1.7
Pelvis	40.5	0.0	0.0	-0.1	0.1	0.2	0.3	0.3	0.5	0.6	0.8	1.1	1.3	1.4

		3	6	11	16	20	2[illegible]	28	33	40	44	48
Rabbit No.2*. Rectum	38.8	0.0	0.0	0.1	-0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.1
Subdiaphragm.	40.5	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.3
Pelvis	40.3	0.1	0.0	0.1	0.2	0.3	0.4	0.4	0.4	0.5	0.5	0.5

		3	4	9	15	20	25	30	36	40	45	61	76	90	96
Rabbit No.3**. Rectum	37.7	x	0.0	0.1	0.2	0.2	0.2	0.2	0.5	0.8	0.8	1.8	1.4	1.6	1.7
Subdiaphragm.	38.8	0.0	0.0	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.7	1.0	1.7	1.4	1.4
Pelvis	38.9	-0.1	-0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.5	0.9	1.1	1.2	1.2

* Electrodes about liver.
** Electrodes about hind legs.

The continued application of diathermy with a fairly large current produced a gradual rise in intraperitoneal temperature. In other regions the rise was not as great; or there was a slight decrease in the regions through which the current did not pass. If the current was low or moderate the body dissipated the heat and the highest temperature [illegible] was not marked. Especially is this true in the rabbit, and unless heavily narcotized and covered with a towel its respirations were sufficiently frequent and deep to prevent a very rapid or extensive rise in temperature. And this despite the fact that the animal may be so heavily narcotized as to be immune to pain. The rise in temperature from diathermy required more time to appear than that induced by a hot water bottle. (Compare Table [illegible] and Table XIX.) Twenty to thirty minutes were usually required to produce an appreciable change with the diathermy. (Table XIX.) The time required to warm up the saline moistened compresses undoubtedly accounts for part of the delay. Unless the rabbit was very heavily narcotized and covered with a towel the rise in temperature was very slight, ranging from 0.1 C. to 1.8 C. in forty-five minutes. In some instances, however, with the electrodes applied about the diaphragmatic area the rectal temperature during the same period of time sank below the original temperature. (Table [illegible].)

Table XX.
Changes Occurring in Intraperitoneal Temperatures when Diathermy Electrodes are Removed from about the Diaphragmatic Region.

	Normal temp.	Diathermy applied (min.)	Degrees increase	Resulting temp.	minutes after diathermy off 1	2	3	5	7
G.pig No.1. Rectum	35.0	4545	-0.2	34.8	34.8	34.8	34.8	34.8	34.9
Subdiaphragmatic	37.8	45	7.0	44.8	44.5	44.3	44.0	43.5	43.2
Pelvis	37.6	45	1.8	39.4	39.5	39.5	39.5	39.5	39.7

	9	10	12	15	20	25	Elevation
Rectum	34.8	34.9	34.9	34.9	35.1	35.1	0.3
Subdiaphragmatic	42.5	42.3	41.7	41.2	40.5	40.1	0.0
Pelvis	39.7	39.8	39.7	39.7	39.6	39.5	0.4

					1	2	3	5	7
Rabbit No.1. Rectum	40.3	62	0.9	41.2	41.2	41.2	41.2	41.3	41.3
Subdiaphragmatic	40.6	62	1.7	42.2	42.3	42.3	42.3	42.4	42.5
Pelvis	40.5	62	1.4	41.9	41.9	41.9	41.9	42.0	42.0

	9	11	12	16	20	24	28	72	Elevation
Rectum	41.3	41.3	41.3	41.4	41.4	41.5	41.5	41.8	0.6
Subdiaphragmatic	42.5	42.5	42.6	42.7	42.7	42.7	42.8	42.0	0.5
Pelvis	42.0	42.0	42.0	42.2	42.2	42.4	42.4	42.6	0.7

					1	2	4	6	7
Rabbit No.2. Rectum	38.3	48	0.1	38.4	38.4	38.4	38.4	38.4	38.4
Subdiaphragmatic	40.5	48	0.3	40.8	40.8	40.9	40.8	40.8	40.8
Pelvis	40.3	48	0.5	40.8	40.8	40.9	40.8	40.8	40.8

	9	10	12	15	20	25	29	Elevation
Rectum	38.5	38.5	38.5	38.6	38.6	38.7	38.7	0.3
Subdiaphragmatic	40.8	40.8	40.8	40.8	40.8	40.8	40.8	0.1
Pelvis	40.8	40.8	40.9	40.9	40.9	40.9	40.9	0.1

The discontinuance of the diathermy current about the liver was followed by a prompt and definite decrease in the temperature beneath the diaphragm, and by a small but constant and definite increase in the temperature of both rectum and pelvis.

Table XXI.
Changes Occurring in Intraperitoneal Temperatures
when Diathermy Electrodes are Removed
from the Hind Legs.

	Normal temp.	Diathermy applied (min.)	Degrees increase	Resulting temp.	Minutes after diathermy off.				
					1	2	3	5	7
G.pig No.1. Rec.	34.3	45	10.7	45.0	45.2	45.3	45.4	45.0	44.6
Subdiaph.	37.8	45	1.5	39.3	39.3	39.3	39.3	39.3	39.3
Pelvis.	37.8	45	6.7	44.5	44.5	44.7	44.7	44.6	44.6

	Normal temp.	Diathermy applied (min.)	Degrees increase	Resulting temp.	1	2	3	4	6	10	15	19	23	28	33	37	Elevation
Rabbit No.1. Rec.	37.7	96	1.7	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.2	38.5	38.5	38.2	38.1	0.0-
Subdiaph.	38.8	96	1.4	40.2	40.3	40.3	40.3	40.3	40.4	40.4	40.5	40.5	40.6	40.6	40.6	40.7	0.7
Pelvis.	38.9	96	1.2	40.1	40.1	40.2	40.2	40.3	40.4	40.4	40.5	40.5	40.6	40.6	40.7	40.7	0.7

The discontinuance of the diathermy current applied to the hind legs caused a constant increase in the rectal and pelvic temperatures, and a smaller increase in the subdiaphragmatic temperature at times. (Table XXI.)

The above phenomen is undoubtedly due, in whole or in part, to a redistribution of the blood of the body from the areas in the diaphragmatic field. With the discontinuance of the diathermy the current of blood which has been flowing rapidly through this region is free to return to other areas, presumably less hyperaemic, and the increase in temperature results. That the skin, muscle, and solid viscera are especially concerned in the changes during diathermy application we can understand from the following statement by Sampson[2], "The heat found in a given part from the passage of a given amount of current through it varies as its resistance, that is........through tissues of varying degrees of resistance, then the more resistant tissues will generate the most heat."

2. C. M. Sampson; Practice of Physiotherapy; p.140.

EXPERIMENT FOUR-EXPOSURE OF VISCERA

Table XXII.
Comparison of the Temperature of the Intestines Remaining Just Inside the Peritoneal Cavity and Those Brought Outside the Peritoneal Cavity and Expposed.

time in minutes

	0	2	5	12	15	20	25	28	60	202
G.pig No.1. In.	35.7	35.4	35.2	35.1	35.2	35.3	35,7	35.8	35.6	35.0
Outside.	35.7	29.6	28.7	28.1	28.0	28.2	28.4	28.5	29.5	31.5

	0	2	5	10	15	19	25	30	41	45	74
G.pig No.2. In.	36.8	36.8	36.7	36.7	36.8	36.8	36.8	36.8	more	36.3	35.0
Outside	36.8	31.8	31.3	31.0	30.9	30.9	31.0	31.7	intes-	35.6	35.0
									tine		
									out		

	0	2	5	7	15	22
G.pig No.3. In.	37.5	37.3	37.2	37.2	36.8	36.6
Outside	35.4	34.9	34.6	34.5	33.9	33.2

	0	2	5	10	15	20	25	30	53
G.pig No.4. In.	38.8	37.4	37.2	37.2	37.3	37.5	37.7	37.5	37.3
Outside	38.8	35.8	34.0	32.2	31.5	31.0	30.5	30.8	31.0

	0	148	303
Rabbit No.1.Inside.	37.8	33.4	30.4
Outside.	37.8	23.1	26.4

	0	3	30	60	90	125
Rabbit No.2.Inside.	40.0	40.1	40.1	40.0	40.0	39.3
Outside.	38.8	38.9	38.2	28.0	27.9	27.1

Viscera were brought outside the peritoneal cavity through a midline abdominal incision. Viscera exposed on the outside of the abdominal cavity showed a definite decrease in temperature in a limited time compared to a very nominal decrease in temperatuse in a limited time just inside the peritoneal cavity. If only small masses of intestine were brought out the temperature in the external mass would decrease five to eight degrees in thirty minutes. This may be partially due to a constriction of the circulation following evisceration through a small incision. If larger masses were exposed the

temperature of the external mass approached very nearly (in time equalled) the temperature of the inside of the peritoneal cavity. This decline of the internal temperature was about 2.0 C. below the beginning temperature in one to one and one-half hours. If further exposure continued over a prolonged period there was a gradual decline in both visceral temperatures; in which the decline of the external temperature became the faster. (Table XXII.)

Table XXIII.
Comparison of the Temperature of Various Intraperitoneal Regions after Exposure of Abdominal Viscera Outside the Peritoneal Cavity.

	Rectum	Above lower parietes	Beneath upper parietes	Center mass of intestines	Pelvis	Beneath the diaphragm	Just inside peritoneal cavity	Mass of exposed viscera	Surface of exposed viscera	Air
G.pig No.1.	36.1	37.2	37.4	37.9	37.1	38.0	36.8	31.8	28.9	27.4
36 min. after	33.9	36.6	37.0	36.6	36.5	36.3	36.3	34.8	32.2	32.2
Decrease.	2.2	0.6	0.4	1.3	0.6	1.7	0.5	-3.0	-3.3	---
G.pig No.2.	34.2	36.9	37.4	37.0	37.3	37.3	36.8	31.4	26.9	25.4
568 min. after	32.9	34.9	35.1	34.7	34.9	34.5	34.5	33.1	27.3	25.6
Decrease.	1.3	2.0	2.3	2.3	2.4	2.8	2.3	-1.7	-0.4	---
Rabbit No.1.	38.9	39.6	40.0	39.9	39.9	39.8	39.5	39.3	31.8	28.8
31 min. after	38.8	39.1	39.6	38.8	39.4	38.9	38.2	38.1	33.9	28.8
Decrease	0.1	0.5	0.4	1.1	0.5	0.9	1.3	1.2	-2.1	---
Rabbit No.2.	37.8	38.9	39.1	39.1	39.1	39.1	37.8	33.0	29.7	28.6
317 min. after	30.9	32.3	32.8	33.8	32.2	31.0	30.6	26.4	25.1	24.4
Decrease.	6.9	6.6	6.3	5.3	6.9	8.1	7.2	6.6	4.6	---

When abdominal viscera had been exposed for considerable periods of time decreases in the temperatures of the exposed viscera and of various intraperitoneal regions occurred. These varied fairly constantly according to the position. The least change usually occurred beneath the upper parietes, usually less than 0.1 C. in an hour or more of exposure. The change above the lower parietes was about the same, the amount of change being influenced somewhat by the temperature of the table upon which the animal was placed. The change just inside the abdominal incision was also small, with the temperature values both before and after the exposure lower than those for the rest of the intraperitoneal cavity. The change in the pelvis was usually slightly greater than that beneath the upper parietes. The amount of change in the rectal temperature was the most variable, and depended largely upon the difference between the rectal and the general body cavity temperature values which

were present at the beginning. The greatest decrease in temperature was, usually beneath the diaphragm. The change in the mass of intestines remaining in the abdomen was next greatest. The exposed viscera usually had a later elevation in temperature unless very unfavorable conditions intervened, such as interferences with the circulation, or undue duration of exposure. (Table XXIII.)

Table XXIV.
The Temperature Changes Occurring with Careful Handling of the Viscera Remaining Within the Abdominal Cavity.

time in minutes

	0	2	5	9	15	20	25	30	35	45	60	90	130
G.pig No.1.	36.6	36.4	36.4	36.6	36.6	36.6	36.6	36.6	36.6	36.5	36.4	36.3	36.2
				10					37				
G.pig No.2.	37.9	37.3	37.0	37.1	37.2	37.2	37.0	36.5	36.6				
				10					35				
G.pig No.3.	39.0	38.4	38.0	38.0	37.9	37.8	37.7	37.7	37.6				
				10									
G.pig No.4.	39.0	38.7	38.6	38.5	38.5	38.4	38.0	37.8	37.7				
				10						45	60		88
Rabbit No.1	37.5	37.5-	37.5-	37.5	37.5-	37.4	37.4	37.4	37.4-	37.3	37.2-		37.0
			7										
Rabbit No.2.	39.1	38.9	38.9										
					17								
Rabbit No.3.	39.6	39.4	39.1	39.2	39.2								
					13	18							
Rabbit No.4.	39.0	38.7	38.9	39.0	39.1	39.3							
					15	20	25						
Rabbit No.5.	39.8	39.8	39.8	39.9	39.9	40.0	40.0						

When the different viscera were still retained within the abdominal cavity and were handled carefully a change in temperature was absent or not very marked. A decrease of one or two degrees Centigrade in thirty minutes was usually noted.

Table XXV.
Temperature Changes Occurring with Handling and with No Handling of the Exposed Viscera.

time in minutes

		0	5	12	15	18
Guinea pig No.1.	Not handled	28.1	27.8	27.9	28.2	28.5
						20
	Handled*	32.5	32.4	32.1	32.9	33.0

* Previously warmed by towels.

Table XXV continued.

		0	5	11	15	20	
Guinea pig No. 2.	Not handled.	31.0	31.2	30.9	31.0	31.2	abdomen still
		30	43	59	75		
	further opened	35.6	35.4	35.0	34.8		
		0	7	22			
Guinea pig No.3.	Handled.	35.4	34.5	33.2			
		0	5	8	16		
Rabbit No.1.	Not handled.	37.8	37.5	37.3	37.1		
			2	5	15		
	Handled	37.1	35.1	37.2	37.3		

Handling, gently or roughly, of the exposed viscera for some time caused an immediate drop in temperature of 0.4 C. to 3.0 C., followed by a rise to a temperature from 0.1 C. to 2.0 C. higher than before the handling. The decrease was undoubtedly due to more rapid evaporation with more exposure to the atmosphere. The succeeding increase was very likely due to an increased blood supply stimulated by the trauma. (Table XXV.)

Table XXVI.
Comparison of the Temperatures of the Exposed Intestine and its Exposed Mesentery.

time in minutes

		0	5	21	87	95
G.pig No.1.	Surface of intestine	30.5	31.1	28.9	27.0	24.9
	Surface of mesentery	33.5	32.8	30.0	28.9	27.0
	Center of mass of exposed intestines.	35.3	34.6	33.2	31.3	28.2
		0	4	9		
G.pig No.2.	Surface of intestine	25.0	25.5	25.8		
	Surface of mesentery	27.1	29.0	28.3		
	Center of mass of exposed intestines	30.4	32.7	31.5		
		0	9	21		
Rabbit No.1.	Surface of intestine	32.5	34.4	31.9		
	Surface of mesentery	35.0	35.7	32.1		
	Center of mass of exposed intestines	39.0	38.9	39.8		

When the intestinal surface was yet moist from the intraperitoneal secretions its temperature approached that of its own mesentery. At the same time the temperature in the mass of exposed intestines was usually one or two degrees Centigrade warmer. Simultaneous exposure of moist and dry surfaces of the exposed gut showed the moist surface to average about 2.0 C. warmer. The dry surface on the exposed gut was found to be cooler than the simultaneous temperature of its own exposed mesentery. The difference was usually 1.5 C. to 2.5 C., but varied as much as 3.6 C. The temperature in the center of the mass of intestines outside the cavity was 2.5 C to 4.0 C. (or more) greater than that of the exposed mesentery; and 3.5 C. to 6.0 C. (and sometimes more) greater than that of the exposed gut. Likewise it was usually greater than the temperature in the rectum when taken at the same time.

Table XXVII.
The Effect of the Temperature of the Surrounding Air upon the Temperature of the Exposed Viscera.

time in minutes

	0	5	10	45	60	75
G.pig No.1.Atmosphere	28.2	28.6	28.5	29.5	32.2	32.2
Surface of intestines	28.7	28.8	28.8	30.2	30.7	32.2
Center of intestines	31.8	31.0	30.9	35.3	35.1	34.8

	0	10	20	30	33	54	62	79	82	179	187	267
G.pig No.2.Atmosphere	27.2	25.1	26.3	27.9*	29.1	26.8	25.8	26.5	28.0**	24.8	25.6	25.6
Surface of intestines	26.1	26.2	25.6	27.9	25.6	x	25.5	26.5	x	25.0	25.8	27.3**
Center of intestines	26.1	27.9	28.5	30.0	30.3	34.0	33.6	31.8	33.9	x	31.5	33.1

* Lamp (heat) brought closer
** Intestines were just handled

	0	5	20	85	95
G.pig No.3.Atmosphere	29.2	28.2	28.9	26.8	25.7
Surface of intestines	30.5	31.5	28.9	27.0	24.9*
Center of intestines	35.3	x	33.2	31.3	28.2

*Intestines just handled very roughly.

Note the fall in temperature in this animal after very rough handling compared to the rise in temperature in the previous animal after gentle handling.

Table XXVII continued.

	0	10	21	135
Rabbit No.1. Atmosphere	28.8	29.8	25.4	24.4
Surface of intestines	37.8	34.4	29.1	25.7
Center of intestines	39.3	38.9	38.5	37.2

	0	46	153
Rabbit No.2. Atmosphere	x	x	24.4
Surface of intestines	28.9	27.3	25.1
Center of intestines	x	30.5	26.4

The temperature of the surrounding atmosphere exerts a certain influence upon the external or surface temperature of the exposed intestine. This surface temperature tends to become the same as that of the surrounding air if the temperature in the mass of exposed intestines is not too much higher or lower. If a considerable mass of intestines is exposed the temperature of the external mass approaches that of the normal body temperature. Hence if the temperature of the air is within two or three (or sometimes four or five) degrees Centigrade of the animal's body temperature the intestinal surface temperature will be that of the air. When the difference is greater the surface temperature tends to parallel the temperature in the mass of exposed intestines. (Table XXVII.)

Table XXVIII.
The Effect of Hot Wet Towels Placed Over The Exposed Viscera.

time in minutes before (-) and after towels applied

	-8	0*	3	5	10*	15	20	25	30	35
G.pig No.1. Towel on Surface	32.2	43.0	40.0	35.0	40.0	45.0	40.0	35.5	33.0	37.5
Center of Outside Mass of Intestines	34.8	34.9	35.3	35.3	35.6	35.6	35.8	35.5	35.0	35.1
Center of Inside Mass of Intestines	35.3	35.3	35.4	35.5	35.7	35.7	35.8	35.7	35.5	35.5

	-13	0*	2	5	10**	16	20
G.pig No.2. Towel on Surface	25.8	35.6	32.6	28.5	34.1	32.9	33.2
Center of Outside Mass of Intestines	31.5	x	x	x	x	33.3	33.7
Center of Inside Mass of Intestines	34.2	x	36.4	34.7	33.6	35.4	x

	-2	0*	3	9	10	16	21**	25**	30	35	40**
Rabbit No.1. Towel on Surface	30.2	38.1	35.3	36.4	36.3	35.8	38.1	39.9	37.9	36.4	38.5
Center of Outside Mass of Intestines	38.5	38.5	38.5	38.7	38.8	39.1	39.0	39.5	39.5	39.2	38.8
Center of Inside Mass of Intestines	39.8	39.7	39.8	39.8	39.8	39.8	39.9	39.9	39.9	39.9	39.9

* Hot towels applied
** Hot towels reapplied

Hot wet towels at temperatures not to exceed 45.0 C. kept the intestinal surface practically up to the temperature of the mass of exposed intestines. The temperature of the mass of exposed intestines could be raised small amounts, as 0.8 C. to 1.2 C., in ten to twenty minutes. The temperature of the mass of intestines remaining outside the peritoneal cavity was usually not raised over 0.2 C., but might go up to 0.5 C or 0.8 C. if a large mass of intestines were exposed outside the cavity. The surface temperature changed quickly as the towels cooled and were reheated and reapplied; the temperature of the external mass lagged through a set of somewhat similar changes. But the viscera inside had a gradual temperature increase, followed by a gradual temperature decline. (Table XXVIII.)

Table XIX.

The Effect of Cool Wet Towels Placed Over the Exposed Viscera.

time in minutes before and after towels applied

	-2	0*	2	5	10	14	19	25
G.pig No.1. Towel on Surface	x	29.5	31.0	30.0	29.7	29.1	28.9	28.3
Center of Outside Mass of Intestines	35.1	35.2	35.1	34.8	34.4	34.1	34.2	33.8
Center of Inside Mass of Intestines	35.5	35.5	35.5	35.3	35.1	35.0	34.8	34.6

	-1	0*	2	5	10	15	20**	25
G.pig No.2. Towel on Surface	33.2	25.0	33.2	26.0	28.3	27.4	33.0	29.4
Center of Outside Mass of Intestines	33.7	33.7	33.5	33.2	33.3	32.7	32.5	33.5
Center of Inside Mass of Intestines	35.4	35.4	35.4	35.2	34.9	35.1	35.1	35.1

	-1	0*	2	5	10	15***	20	25
Rabbit No.1.Towel on Surface	34.4	26.3	28.0	28.1	23.2	30.0	30.1	30.2
Center of Outside Mass of Intestines	38.9	39.0	38.8	38.8	38.8	38.8	38.5	38.3
Center of Inside Mass of Intestines	40.1	40.1	40.1	40.1	40.0	39.9	39.8	39.8

	-1	0*	2	5	10	15
Rabbit No.2.Towel on Surface	33.1	32.0	31.0	30.0	29.5	31.5
Center of Outside Mass of Intestines	37.8	37.2	37.1	37.3	35.1	33.1
Center of Inside Mass of Intestines	39.9	39.9	39.9	39.3	39.6	39.7

* Cool towel applied
** Towels removed
*** Cool towels reapplied

Cool wet towels at temperatures not below 25.0 C. lowered the intestinal surface temperature of the exposed viscera to which they were applied. The actual temperature varied with the temperature of the towel and the length of time during which it had been applied. The usual surface temperature change was an immediate temperature decline, followed by a rise as the heat of the viscera warmed up the towel. After this same had been reached there was a gradual decline as the moist towek cooled from evaporation and cooled the intestinal surface with it. If the towel became dry the visceral heat then would raise the temperature again. The temperature in the center of the mass of external viscera was usually cooled down from 1.0 C. to 2.5 C. in thirty minutes. The temperature of the mass of intestines yet remaining inside cooled 0.5 C. to 1.0 C. in this same time. (Table XXIX.)

Cool towels applied to exposed viscera caused a very erratic curve of the intestinal surface temperature values. This was usually introduced by an instantaneous sharp drop followed by a slower recovery extending over the succeeding period of fifteen to twenty minutes as shown in Table XXIX.

Table XXX.
Alternating Temperature Changes after Application of Cool Towels to Exposed Viscera.

time in minutes after towels applied

	0	1	2	5	6	7	10	13	15
Rabbit No.1. Towel surface	26.3	x	x	28.1	28.0	28.2	28.2	29.1	30.0
Center of Mass of Outside Intestines	39.0	38.9	38.8	38.8	38.9*	38.9	38.8*	38.8	38.8
Center of Mass of Inside Intestines	40.1	x	x	40.0	40.0	40.0	40.0	39.9	39.9

	0	1*	2*	5*	10*	15	20	25	30
Rabbit No.2. Towel surface	30.0	28.4	30.3	29.6	29.7	29.5	30.0	30.1	30.2
Center of Mass of Outside Intestines	38.[illegible]	x	38.[illegible]	x	x	x	x	38.5	38.4

	0	2	2½	3	4	4½	5½
Rabbit No.3. Towel surface	34.[illegible]	26.0	x	x	x	x	x
Center of Mass of Outside Intestines	x	x	36.7*	36.8*	36.4*	36.2	36.0

	0	1	2	4	4½	5	5¼	5½
Rabbit No.4. Towel surface	33.1	32.0	x	x	x	x	x	x
Center of Mass of Outside Intestines	37.3	37.2*	37.1	37.1½*	37.1*	37.1½*	37.2	37.2½

	5¾	6	6½	6¾	8	10
Rabbit No.4. Towel surface	x	x	x	x	x	x
Center of Mass of Outside Intestines	37.2*	37.2½*	37.3	37.2*	37.1-	37.1*

* Note change of direction of temperature from higher to lower then higher, and vice versa.

The cool towels applied to the exposed viscera in addition to the gross changes in surface temperature of the exposed viscera as just previously shown also caused simultaneously fluctuating curves in the values not only of the surface temperatures beneath the towels but also in the temperatures in the center of the mass of intestines outside of the peritoneal cavity. These consisted of two to as many as eight direction fluctuations, each ranging in value from 0.1 C. (0.5 C.) to 0.4 C. The changes were somewhat difficult to decipher because of their small amplitude and short duration. The probable explanation is that they were produced by vascular spasms which were induced by the coolness of the towels; the minute decreases in temperature following a spasm being superseded by an increase in temperature as the spasm was temporarily released allowing the freer influx of arterial blood. (Table XXX.)

CLINICAL OBSERVATIONS

A. In the Operating Room.

In taking temperature determinations at the operating table we confirmed the findings previously obtained with the animals in so far as our limited time allowed. This is a field which should yield fruitful results to further observations.

Chart A.
Hernia and Hydrocele Operation

		Temperature C.
8:35	Skin incision	
8:43	Subcutaneous tissue	33.2 C.
8:43	Exposed testicle	30.9 C.
8:44	Testicle replaced into scrotum	
8:48	Subcutaneous tissue	32.4 C.
8:58	Testicle withdrawn for temperature determination	35.4 C.

In one instance in doing a combined inguinal hernia and hydrocele operation the temperature of the surface of the testicle rose towards normal 4.5 C. in fifteen minutes after it had been replaced within the scrotum. The decreased temperature had resulted following the incision, exposure, and removal into operating room atmospheric temperatures. (Chart A.)

Chart B.
Intestinal Resection.

8:25	120 mg. novacaine.	
8:30	Incision.through.left.rectus.muscle...	
8:36	Omentum	....................36.0 C.
8:37	Parietal peritoneum	

Chart B continued.

8:38	Jejunum, inside abdomen, but exposed.....	36.7 C.
8:38 to 9:22	Removal of left one-half of transverse colon and part of descending colon.	
9:22	Parietal peritoneum, well posteriorly....	35.1 C.
9:23	Omentum.................................	35.4 C.
9:23	Stomach.................................	36.1 C.
9:24	Jejunum, of left upper quadrant, not previously exposed........................	35.9 C.

In this case in which temperatures were taken during an operation for intestinal resection it was noted that, as usual, those intestines well away from the incision and not exposed had the highest temperature value. (Chart B.)

Chart C.
Cholecystectomy.

8:33	Air.....................................	36.2 C.
8:34	Omentum, surface of	34.4 C.
8:35	Subcutaneous fat in wall of wound	34.6 C.
8:35	Under surface of liver	36.3 C.
8:49	Upper surface of liver after cholecystectomy cholecystectomy..........................	[illegible] C.
8:55	Exposed liver surface	37.0 C.
9:09	Subcutaneous fat, as above	35.6 C.
9:22	Skin after operation	34.0 C.

In an instance in which operation was performed for cholecystitis the determinations read by a student nurse seemed to indicate a rise of temperature in the space between the liver and the diaphragm of 1.7 C. in the fifteen minutes elapsing during the removal of the gallbladder. The operating light was focused in the wound during this time, as usual. In another cholecystectomy (shown in Chart C) there seemed to be a higher temperature in the region between the liver and the diaphragm than in the other tissues examined.

Chart D.
Appendectomy.

11:04	Atmosphere above operating table.......	30.2 C.
11:04	Subcutaneous tissue	34.1 C.
11:06	Caecum, having been exposed for two minutes minutes	32.9 C.
11:12	Skin	34.7 C.

Chart D continued.

11:33	Parietal peritoneum, unexposed	37.7 C.
11:42	Subcutaneous tissues	34.4 C.
11:51	Skin near wound	34.4 C.
11:52	Cheek	32.4 C.
11:53	Left clavicular region	32.6 C.
11:56	Dorsum of right foot	32.2 C.
11:57	Chest, midline	33.3 C.

In an operation for appendicitis under general anesthesia, with the surrounding air definitely cooler than the body temperature, it was noted that the temperature of the exposed caecum sank definitely and rapidly below the temperature of the incised tissues of the wound's edges; and these in turn were much cooler than the parietal peritoneum which had been unexposed. (Chart D.) Although these temperatures are lower than the average body temperatures (37.0 C.) they are yet higher than other body surface temperatures of this patient. (Chart D.)

Chart E.
Prostatectomy.

8:34	Subcutaneous fat of abdominal wall	36.0 C.
8:36	Surface of bladder	37.5 C.
8:42	Bladder mucosa	38.3 C.
8:42 to 9:01	Removal of prostate.	
9:01	Bladder mucosa	35.2 C.
9:13	Subcutaneous fat	33.3 C.

In a one-stage suprapubic operation for removal of the prostate it was noted that the internal bladder temperature (mucous membrane) decreased 2.3 C. during nineteen minutes, the prostate having been removed during that interval. (Chart E.)

B. On the Wards.

Decreases in the intraperitoneal temperatures of two patients on the wards following the application of ice bags to the abdomen were studied.

Chart F.
Ascites from Hepatic Cirrhosis.

Temperature reduction beneath parietes of left lower quadrant of a male, age fifty-four years, with abdominal ascites (hepatic cirrhosis).

Chart F. continued.

time elapsed in minutes

37.0	2	3	5	10	14	19	25	30	34
37.7	37.3	37.1	36.6	35.0	34.1	34.2	34.0	33.9	33.5

The first patient was a male, aged fifty-four years, with marked abdominal ascites from hepatic cirrhosis. Following one of the paracentesis procedures (through the midline below the umbilicus) a special terminal constructed partly out of a catheter (No. 12 French) was inserted through the cannula and directed toward the left lower quadrant. An ordinary ice bag with cover was applied. The intraperitoneal beneath the abdominal parietes was reduced 4.2 C. (37.7 minus 33.5 C.), or 7.6 Fahrenheit, in thirty-four minutes. (Chart F.)

Chart G.
Ascites from Cardiac Decompensation.

Temperature reduction beneath parietes of right lower quadrant in a female, age forty-eight years, with abdominal ascites (cardiac decompensation).

0	2	3	5	10	15	19	25	29	34	40	46
38.2	37.8	37.8	37.3	36.5	34.8	33.7	31.7	30.8	30.3	29.6	29.4

The second patient was a female, aged forty-eight years, with marked abdominal ascites following cardiac decompensation. Here also following one of the paracentesis procedures the special terminal was inserted and directed toward the right lower quadrant. The intraperitoneal temperature beneath the parietes was reduced 8.8 C. (38.2 C. minus 29.4 C.), 15.7 degrees Fahrenheit, in forty-six minutes. (Chart G.)

SUMMARY

(1). The normal intraperitoneal temperature of guinea pigs and rabbits varied for the individual and varied in the individusal in different locations. For the different individuals the comparative temperature changes were rather similar.

(2). Cold, applied for thirty minutes or more by means of an ice bag, lowered the subjacent intraperitoneal temperature an average of 11.3 C. in twelve guinea pigs; lowered the temper-

ature an average of 7.2 C. in six rabbits; and lowered the temperature 4.2 C. and 8.7 C. respectively in the two human subjects.

(3). Shivering of the animal tended greatly to reduce the rate of decrease of the temperature. The temperature actually increased 2.4 C. in one case in which convulsions also intervened.

(4). Heat, approximately 50.0 C., applied for thirty minutes or more, by means of a hot water bottle, raised the subjacent intraperitoneal temperature an average of 4.8 C. in twelve guinea pigs; and raised the temperature an average of 6.0 C. in six rabbits.

(5). Cold caused a greater decrease in intraperitoneal temperature below normal than heat does above normal. Cold also produced its change in less time. After a latent period of variable length both cold and heat have a period of maximum change per unit of time, followed by a much smaller change per unit of time. The maximum difference in temperature between the external and internal surface is theoretically 37.0 C. in the application of cold; and theoretically 13.0 C. (or 15.0 C.) in the application of heat. Actually the difference was not this great.

(6). When the external cold was removed the intraperitoneal temperature slowly approached toward normal. When the external heat was removed the temperature rapidly fell toward normal, and then more slowly sank below normal.

(7). When the intraperitoneal temperature was below normal the application of heat raised the temperature to normal in much less time than was then required to elevate the temperature the same number of degrees above normal.

(8). When the diathermy was applied through the diaphragmatic areas by far the greatest increase in temperature was in the sub-diaphragmatic regions. In the pelvis and rectum, especially the latter, the change was very slight.

(9). With the diathermy applied to the hind legs the major temperature rise was in the pelvis and rectum. In the rabbits with a rapid respiratory rate the subdiaphragmatic temperature rise was about as great as there; in other animals the subdiaphragmatic rise was not nearly as great.

(10). The discontinuance of diathermy when applied about the liver was followed by a slow but constant increase in temperature in the pelvis and rectum for twelve to twenty-five minutes. When diathermy was discontinued from the hind legs an increased temperature occurred in pelvis and rectum and at times a small increase also occurred in the subdiaphragmatic region.

(11). Rough handling of exposed intestines caused a drop in temperature of these viscera; this was shortly followed by a rise to an even higher temperature.

(12). Viscera exposed outside the abdominal cavity showed a decreased temperature compared to the uneviscerated intestines. A small mass of intestines showed a greater drop in temperature than did a much larger mass when exposed, provided the exposure did not last over sixty to ninety minutes.

(13). The dry surface of the exposed viscera approximated that of the surrounding air if the temperature was within two or three degrees of the temperature of the mass as a whole. If the difference was greater the surface temperature tended to parallel the temperature of the mass of exposed intestines.

(14). Exposure of eviscerated intestines over a period of time, especially if the mass of intestines was large, caused a decrease in the temperature within the body cavity.

(15). The exposed dry surface of the gut was about two degrees cooler than the exposed mesentery of the same gut. This exposed mesentery was two or three degrees cooler than the mass of eviscerated intestines.

(16). Hot wet towels aided in keeping up both the temperature of the intestinal surface and the temperature of the mass of intestines to practically that of the uneviscerated intestines.

(17). Cool wet towels lowered both the surface temperature and the temperature of the mass of exposed intestines. The temperature of the inside mass of intestines was lowered 0.1 C. to 1.0 C.

(18). Cool wet towels applied to the surface of the exposed viscera caused a very peculiar curve of temperature values in the mass of exposed viscera. Apparently this was due to arterial spasm stimulated by the coolness of the towels.

(19). At the operating table variations in intraperitoneal temperature and decreases upon exposure were confirmed in human beings.

(20). In one instance a testicle exposed less than eight minutes during a combined hernia and hydrocele operation rose 4.5 CC when replaced inside the scrotum within the following fifteen minutes.

(21). In two patients with abdominal ascites the application

of ice bags , the outside temperature of which approximated 10.0 C. to 12.0 C., reduced the temperature beneath the parietes 4.2 C. and 8.7 C. respectively.

CONCLUSIONS

(1). The therapeutic use of cold applied to the external abdominal wall is accompanied by a decrease in the subjacent intraperitoneal temperature. A decreased temperature but of less degree is found also in neighboring intraperitoneal regions.

(2). The therapeutic use of heat applied to the external abdominal wall is accompanied by an increase in the subjacent intraperitoneal temperature.

(3). Diathermy applied about the diaphragmatic region would be quite effective during an operation in maintaining intraperitoneal temperature in the upper abdomen; and to a less degree in the lower abdomen.

(4). The application of cold, heat, or diathermy to the abdominal wall is followed by a change in the general body temperature as evidenced by the changes in the more distant intraperitoneal regions and in the rectal temperature. The amount of change is influenced by the total body area which is contacted by the thermal agent, by the temperature of the thermal agent, by the length of time the agent is applied, and, especially in the case of diathermy, by the depth of narcosis (light narcosis being accompanied by dyspnoea and a lesser change in temperature).

(5). The temperature of the rectum, both under normal conditions and when under the influence of thermic agents applied to the abdominal wall, is markedly variable when compared to the temperature of the pelvis and other regions within the abdominal cavity. Hence the value of the rectal temperature as an indicator of the exact temperature within the abdominal cavity, and presumably other regions of the body, is seriously questioned. If, as seems at times, the rectal temperature represents a purely local temperature determination its value then must be only suggestive rather than decisive.

(6). Since the rectal and pelvic temperatures continue to rise for fifteen to twenty-five minutes after removal of the diathermy applied about the diaphragmatic region, we can assume that great readjustments are taking place in the circulation, resulting in both the redistribution of and the releasing of heat. It is interesting to speculate upon the possible extermely high intraperitoneal temperatures that could occur with a patient in a Turkish bath or any thermal or electrical contrivance for elevating the body temperature. It is possible that the intraperitoneal temperature

would be enormously higher than even the very high oral or rectal temperature that could be thus obtained.

(7). Exposure of and moderate handling of the intestines for sixty to ninety minutes caused no changes in temperature which would seem to be deleterious. Possibly this fact should not be lost sight of in operations upon the abdomen.

(8). Hot wet towels are of proven value both in retaining the practically normal surface temperature and the glistening appearance of the exposed intestines, and in maintaining the normal temperature of the mass of exposed intestines.

(9). When cool towels are once applied, if unfortunately they are the only ones to be obtained, they should not be changed frequently, but should be allowed to remain in situ as long as needed.

(10). If intestines must be brought out of the abdominal cavity it appears to be extremely important to have an adequate incision, because the partial occlusion of the circulation from inadequate exposure produces a marked decrease in temperature.